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## SUMMARIES IN MICRO-BIOLOGY

For some months the Secretary has been seeking to secure for this Journal and its Department of Summaries, a series of papers from biologists dealing with the chief groups of microscopic plants and animals. It has not been the purpose to present a complete survey of any of the groups. The wish has been rather to bring together in one article a statement of the following things:—general biology, the method of finding, the methods of capture and of keeping alive and cultivating in the laboratory; how best to study; the general technic; the most accessible literature; and a brief outline of the classification, with keys for the identification of at least the more representative genera and species of the micro-organisms likely to be found by the beginning students in the United States.

It has been felt that the getting together of such data as this, while not a contribution to science, would be a contribution especially to isolated workers and to teachers and students in the high schools and smaller colleges.

Papers have already appeared treating the aquatic Oligochetes, the Melanconiales, the Rusts, the Black Moulds, the Powdery Mildews, the Cephaline Gregarines, and the Conjugate Algæ. The following is the seventh paper of the series. It is proposed to have such synopses from time to time until the more common American species of such groups as the following have been covered: The Blue-green Algæ, non-conjugating Green Algæ, Downy Mildews, Yeasts, other Hyphomycetes, Smuts, Rhizopods, Infusoria, Turbellaria, Bryozoa, Water Mites, etc.—[Editor.]

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## FREE-SWIMMING FRESH-WATER ENTOMOSTRACA OF NORTH AMERICA\*

BY ADA L. WECKEL

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### 1. General.

The class of animals known as Crustacea are divided into two sub-classes, Malacostraca and Entomostraca.

To the Malacostraca those Crustacea belong which are highly organized; usually of considerable size; and with a fixed number (nineteen pairs) of appendages. To this class belong the crayfish, freshwater shrimp (*Gammarus*), wood louse (*Oniscus*), and most of our common Crustaceans.

The Entomostraca, with which it is the purpose of this paper to deal, include Crustacea which are of comparatively simple organi-

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\*Contribution from the Biological Department of the Oak Park and River Forest Township High School, Oak Park, Illinois. The writer is indebted to the United States National Museum and to Dr. V. E. Shelford for specimens used in the preparation of this paper.

zation, usually small, often microscopic, and with a variable number of pairs of appendages.

## 2. Habitat, Collecting, Preparation.

Some species of Entomostraca occur in countless numbers and, from the standpoint of food supply, are among the most important aquatic invertebrates. They occur in any stagnant, or semi-stagnant, water and are commonly called "water fleas." These minute animals are liable to be found in or near any of the fresh waters: ponds (permanent or temporary), marshy pools, rivers, and lakes.

They occur, and may be taken free swimming in the running and open waters, but they are most easily collected in decaying organic matter and on the stems and roots of submerged vegetation.

If the material thus collected is brought into the laboratory, one is certain to find many of these small animals darting about the sides of the glass jars. These can readily be detected by their motions and can be easily picked up with a pipette. Others tend to collect in the debris which sinks to the bottom of the jar. From there they can also be obtained with a pipette.

If the water is kept fairly clear these forms multiply very rapidly, and their number is limited only by the food supply. It is best to guard against too great foulness from the decomposition of organic matter, which usually results in the bacteria and infusoria destroying much of the other life in the jar.

Many of the Entomostraca are beautifully transparent and can thus easily be studied alive under the microscope. The identification of most species depends upon external structures, usually of the appendages. For this purpose, the appendages must frequently be removed, a rather tedious task for a beginner.

If one does not desire to study these forms alive, or if it is necessary to dissect them, they are readily killed and satisfactorily preserved by putting them into vials containing 80% alcohol. If the specimens become opaque, they will become transparent enough for study by mounting them in a drop of 10% glycerine.

### 3. Systematic Survey of Entomostraca.

#### CLASS CRUSTACEA.

- I. Sub-class Malacostraca.
- II. Sub-class Entomostraca.
  - Order 1 Phyllopoda.
    - sub-order Branchiopoda.
    - sub-order Cladocera.
  - Order 2 Ostracoda.
  - Order 3 Copepoda.
    - sub-order Eucopepoda.
    - sub-order Branchiura.
  - Order 4 Cirripedia.

The general characteristics of the orders of the Entomostraca are:

#### *Order 1 Phyllopoda.*

In these at least four pairs of swimming feet bear leaf-like respiratory plates. The body is generally well segmented, and is usually protected by a shield-like or bivalved shell. (Fig. 1).

#### *Order 2 Ostracoda.*

Small, usually laterally compressed Entomostraca, with a bivalved shell. Body indistinctly segmented, or unsegmented; rudimentary abdomen; only seven pairs of appendages. (Fig. 8).

#### *Order 3 Copepoda.*

Elongated Crustaceans, with distinct segments, except in certain parasitic forms. There is no dorsal shell. There are five pairs of biramous (two branched) thoracic appendages, but the last may be rudimentary or absent. Abdomen without appendages, and of its five segments the first two are sometimes united. Females carry eggs in external ovisacs. Many are ecto-parasitic and in structure are often very degenerate (Fig. 9).

#### *Order 4 Cirripedia.*

*Marine* Crustaceans. Barnacles and some allied degenerate parasites.

An exhaustive study of the Entomostraca is made with considerable difficulty because of their small size, the great number of genera and species (especially of *Cladocera* and the genera *Diaptomus* and *Cyclops*), the differences between males and females, and, finally, because many forms are parasitic.

The scope of this paper is such as to exclude all the marine forms which include all of the Cirripedia. All of the parasitic forms have also been omitted because they are too difficult for a beginner.

In most cases keys are included for the determination of all known species. These complete keys are given because it seems inadvisable to select species common to only a given region; also, because frequently the literature containing the keys is inaccessible.

#### 4. Description and Keys.

##### Order 1 Phyllopoda.

The animals belonging to this group differ very considerably in form and in size, in the number of their segments and appendages, as well as in their internal structure. They all, however, agree in the structure of their lobed, leaf-like feet.

This order is divided into two sub-orders:

*a.* Body has numerous segments, and from 10 to about 30, or more, pairs of appendages with respiratory plates. The shell is rarely absent, usually shield-like or bivalved. Heart dorsal organ with numerous openings.....sub-order Branchiopoda.

*aa.* Small laterally compressed body, with few and somewhat indistinct segments. Body, with the exception of the head, which projects freely, is usually enclosed in a bivalved shell. Second antennæ large, used in swimming; 4-6 pairs of swimming feet.....

.....sub-order Cladocera.

##### Sub-order Branchiopoda.

One of the largest fresh-water Branchiopoda is the fairy shrimp, belonging to the genus *Branchipus*, found appearing in early spring in ponds. It is a small, translucent swimming animal from one-half to three quarters of an inch in length. It is most active when the sun is low, both in the morning and the evening, when it is continuously jerking about among the water weeds.

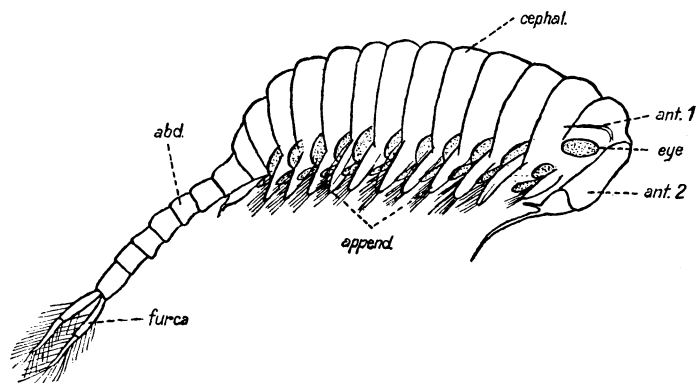


Fig. 1. A Branchiopoda. *Eubranchipus vernalis* Verrill. Length 10 mm. Abd., Abdomen; ant. 1, first antenna; ant. 2, second antenna; append., appendages with respiratory plates; cephal., cephalothorax.

The male is much smaller than the female, and is comparatively rare. In fact, it is never seen at all except at certain seasons and under certain conditions. The males are distinguished from the females principally by the modification of the second antennæ to form a prehensile apparatus. The eggs during development are carried about by the female.

#### Sub-order Cladocera.

The members of this sub-order are commonly called "water fleas." It is a very large order containing about eight families, which include about eighty species reported to occur in North America.

As stated above, the body is small, laterally compressed, with few, and somewhat indistinct segments. The shell is usually bivalved, and the head often projects freely from it. The first antennæ are short. The second antennæ are large, two branched organs, and constitute the chief organ of locomotion. They bear numerous long setæ.

There are four to six pairs of legs. These are not always swimming legs, but in many cases have the form of cylindrical ambulatory or prehensile organs.

The abdomen is flexed ventrally. It consists, usually, of three free segments, as well as the terminal anal portion. The anal portion begins with two dorsal tactile setæ and ends with two hooks forming the caudal forks (furca).

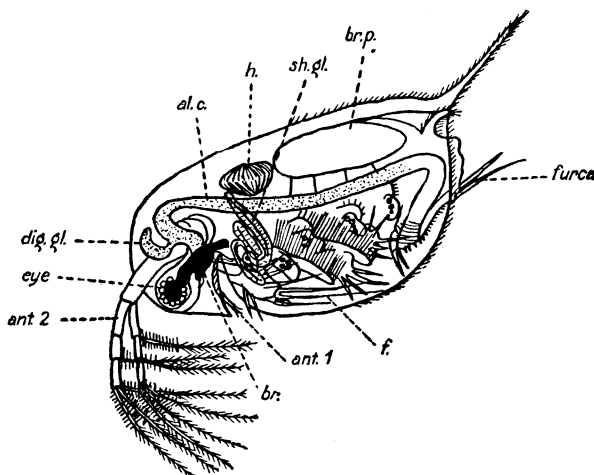


Fig. 2. A Cladocera. *Daphnia* sp?. Al. c., alimentary canal; br. p., brood pouch; br., brain; dig. gl., digestive gland; f., legs; h., heart; sh. g., shell gland. Other labels same as in Fig. 1. (After Claus).

Between the abdomen of the female and the posterior part of the carapace is a large brood pouch in which the eggs are stored. The males are usually smaller and much rarer than the females. Periodic parthenogenesis is very common. The eggs are of two kinds, the so-called "summer eggs" with relatively little yolk, which develop rapidly without fertilization, and the so-called "winter eggs," containing much yolk, which require to be fertilized and then develop slowly.

The paired eyes have fused into a single organ, which forms a large continually trembling, frontal eye.

Many of the Cladocera have an extraordinarily grotesque form owing to the peculiar shape of the head, the immense antennæ, and the great hump-like brood pouch.

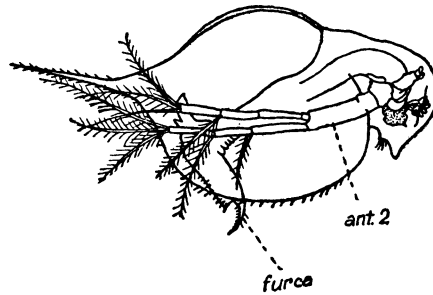


Fig. 3. A Cladocera. *Daphnia longiremis* Sars. Female. Length 1-1.5 mm. Body encased in a bivalved shell. (After Birge).

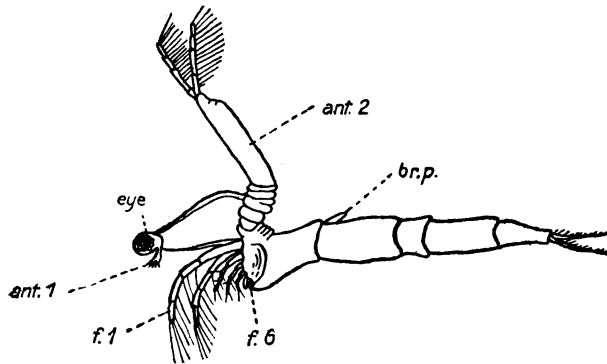


Fig. 4. A Cladocera. *Leptodora hyalina* Lilljeborg. Female. Length 8 mm. F. 1 to f. 6, legs. Body with rudimentary shell or carapace. (Modified from Gerstaecker).

The sub-order Cladocera is divided into two great groups, Calyptomera and Gymnomera; in the former the body and thoracic appendages are encased in a bivalved shell; (Figs. 3 and 5); in the latter, the carapace is rudimentary, giving little or no protection to the body. (Figs. 4 and 6).



## SYNOPSIS OF THE FAMILIES.\*

## I. Calyptemora.

- a.* Six pairs of similar, non prehensile, foliaceous feet whose margins are fringed with hairs arranged like the teeth of a comb...Ctenopoda.
- b.* Second pair of antennæ biramous, with laterally compressed articulations furnished with numerous hairs.....family *Sidida*.
- bb.* Second pair of antennæ uniramous in the female (among the males the rudiment of a second ramus), sub-cylindrical, furnished with only three apical hairs; animal surrounded by a gelatinous envelope.....family *Holopedida*.
- aa.* Five or six pairs of feet, the anterior pair being prehensile with their laminæ destitute of branchiæ; the second pair of antennæ with cylindrical articulations furnished with few hairs.....Anomopoda.
- b.* Ventral ramus of the posterior antennæ with three articulations, dorsal with four.
  - c.* Five pairs of feet, with large interval between the last two pairs .....family *Daphnida*. (Figs. 2 and 3).
  - cc.* Five or six pairs of equidistant feet,
    - d.* First pair of antennæ in the female long, immobile, proboscis-like, with the sensorial hairs remote from apex. ....family *Bosminida*. (Fig. 5).
    - dd.* First pair of antennæ in female long, mobile, with sensorial hairs apical, intestine simple or convolute. ....family *Lyncodaphnida*.
  - bb.* Second pair of antennæ with three articulations in each ramus,
    - c.* Five or six pairs of equidistant feet; intestine circumvolute.....family *Lynceida*.

## II. Gymnomera.

- a.* Feet bare, subcylindrical, all prehensile,
  - b.* Four pairs of prehensile feet armed with strong claws provided with maxillary processes at the base. ....family *Polyphemida* (Fig. 6).
  - bb.* Six pairs of simple feet without maxillary processes. ....family *Leptodorida*. (Fig. 4).

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\*From Fordyce, C. The Cladocera of Nebraska. Trans. Amer. Mic. Soc., XXII, pp. 119-174, pl. XXII-XXV, 1900.

The genera and species of this order are so numerous that it does not seem possible, nor advisable, to attempt to include a key for their determination. For this purpose, reference should be made to the papers by Dr. Birge.

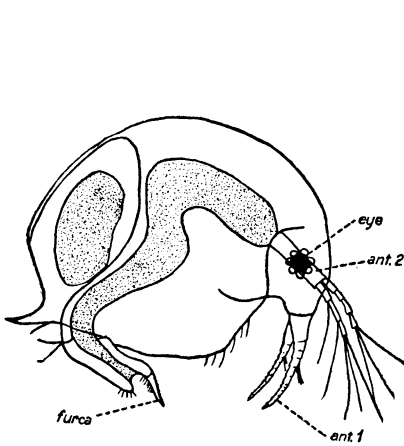


Fig. 5. *Bosmina obtusirostris* Sars. Family Bosminidae. Female. Length 0.6 mm.

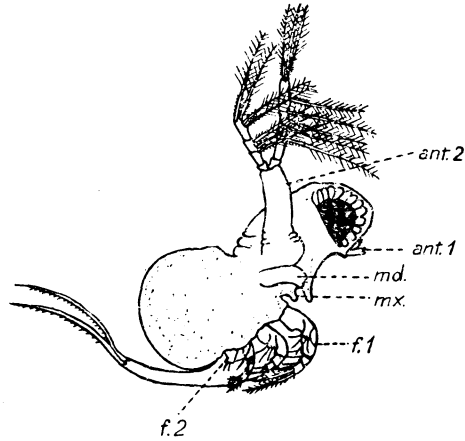


Fig. 6. *Polyphemus pediculus* de Geer. Family Polyphemidae. Female. Length 1 mm. (Modified from Gerstaecker).

## Order 2 Ostracoda.

The Ostracoda are small Crustacea, the body consisting of very few, about eight, segments, and being completely enclosed in a carapace, which has the form of a bivalved shell. No doubt, the casual observer often mistakes the Ostracoda for small mollusks. The resemblance, however, is all on the surface. The two valves of the shell are closed by a large adductor muscle, the insertion of which forms distinct markings on the shell.

At the anterior end is a median eye. There are only seven pairs of appendages. The two pairs of antennæ are large and uniramous, one branched, and are used as creeping and swimming legs.

The mandibles are large. Each bears a leg-like palp, which is usually three segmented and can be used as a leg.

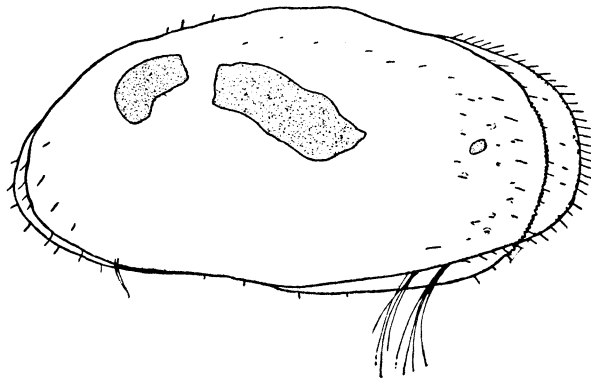


Fig. 7. An Ostracoda, *Cypris pellucida* Sharpe. Length 1.2 mm. Shell showing size and relation of two valves.

The mandibles are followed by the first pair of maxillæ, which are distinguished by the great development of their basal portion and by the reduction of the palp. The basal joints of the first maxillæ sometimes bear a large comb-like plate, which by its swinging movements aids the function of respiration. A similar branchial plate may occur also on the two following appendages, which sometimes have the form of jaws.

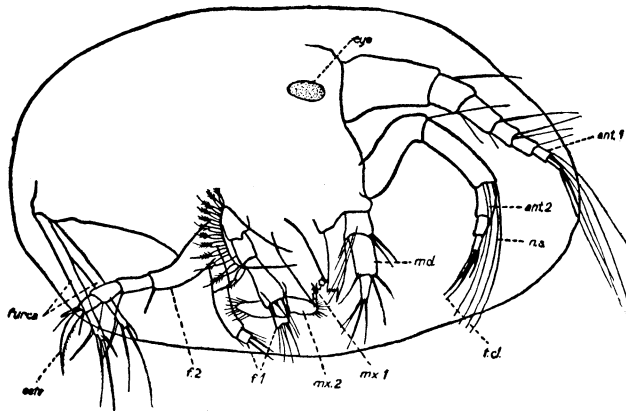


Fig. 8. *Cypris pellucida* Sharpe, with appendages. Antennae show long hairs, n. s. (natatory setae) used in swimming; md., mandible; mx. 1 and mx. 2, first and second maxillae; f. 1 and f. 2, first and second feet; t. cl., terminal claw.

The only thoracic appendages are two pairs of slender legs.

The abdomen is devoid of legs and ends in a caudal fork (*furca*) or has the form of a plate armed with spines and hooks.

The Ostracoda are marine and fresh water animals that can be divided into several families, differing slightly in habits and in structures correlated with these habits.

The fresh water members of this group known to occur in North America belong to three families: Cyprididæ, Cytheridæ, and Darwinulidæ.

	FAMILIES.	GENERA.
Ostracoda	Cyprididæ	<ul style="list-style-type: none"> <li>Notodromas.</li> <li>Chlamydotheca.</li> <li>Herpetocypris.</li> <li>Spirocypris.</li> <li>Cypris.</li> <li>Cyprinotus.</li> <li>Cypridopsis.</li> <li>Potamocypris.</li> <li>Cypria.</li> <li>Cyclocypris.</li> <li>Candona.</li> <li>Typhlocypris.</li> </ul>
	Cytheridæ	<ul style="list-style-type: none"> <li>Limnocythere.</li> </ul>
	Darwinulidæ	<ul style="list-style-type: none"> <li>Darwinula.</li> </ul>

#### I. Family Cypridæ.

Shell generally thin and horny, valves equal or but slightly unequal in size. Eyes simple, usually confluent, sometimes wanting. First antennæ slender, usually seven-jointed. Second antennæ four or five jointed. Mandibles strong, apex strongly toothed, palp four jointed, with a branchial plate at base. Two dissimilar pairs of feet; the anterior pair ambulatory, the posterior pair not used for locomotion, bent backwards within the valves. Antennæ commonly with natatory setæ (Fig. 8). Furca usually well developed, elongated, very mobile, and bearing two or three apical claws.

The principal characteristics used for the determination of the species of this family are:

1. Length of natatory setæ as compared with end claws of antennæ.
2. Number and kind of setæ on end segment of second foot.
3. Size and armature of furca.

Key to the sub families, genera, and species of the fresh-water forms known to occur in North America belonging to the family Cyprididæ.\*

1. *Sub-family Notodromadinæ.*

Natatory setæ commonly reaching beyond end claws. Second feet usually with three terminal setæ of different length, two backwardly directed and the middle one sometimes claw-like. First maxillary process usually armed with six strong spines.

a. Second antennæ 6 segmented in both sexes. Second feet normal. Terminal seta of caudal ramus missing. Branchial plate on second maxilla of 2 setæ.....Genus *Notodromas*.

GENUS NOTODROMAS, LILLJEBORG.

Shell high, smooth. Two eyes, separate. Sexual. Other characteristics as given above.

a. Female with spine-like projection at lower posterior extremity of shell. Shell noticeably quadrangular. Minnesota; Indiana; Alabama.....  
.....N. *monacha* O. F. Müller.

2. *Sub-family Herpetocypridinaæ.*

Natatory setæ shortened. No swimmers. Second foot with a beak shaped end segment and a short claw.

a. Second segment of first foot with 2 setæ on anterior margin. Three spines on first maxillary process, the first one commonly toothed.....  
.....Genus *Chlamydotheca*.

aa. Second segment of first foot normal, but 1 seta. Two spines on first maxillary process plainly toothed. Length 1.8 mm. or more. Two setæ on first segment of first foot.....Genus *Herpetocypris*.

\*Compiled and adapted from: Sharpe, R. W. Report on the Fresh Water Ostracoda of the U. S. Nat. Mus., including a Revision of the Sub-families and Genera of the Family Cyprididæ. Proc. U. S. Nat. Mus. XXVI, pp. 969-1001, pl. LXIV-LXIX, 1903.

## GENUS CHLAMYDOTHECA, SAUSSURE.

This genus is at once distinguished by the presence of two setæ on anterior margin of second segment of first foot, instead of one, as in other fresh-water Ostracoda.

- a.* Furca about 24 times as long as wide, its dorsal margin faintly toothed for one-half its length; shell broadly oval from above. Mexico....  
.....*C. mexicana* Sharpe.
- aa.* Furca about 18 times as long as wide, its dorsal margin faintly ciliate its entire length. Shell wedge shaped anteriorly from above. Texas.....*C. azteca* Saussure.

## GENUS HERPETOCYPRIS, BRADY AND NORMAN.

Natatory setæ rudimentary. No swimmers. Spines of first maxillary process plainly toothed. Length 1.8 mm. or more. First segment of first foot with two setæ. Dorsal seta of furca very small. Sexual or asexual. Three species are reported from North America.

- a.* Length about 4 mm. Furca about 20 times as long as wide.....  
.....*H. barbatus* Forbes.
- aa.* Length between 2 mm. and 3 mm. Terminal claw of second foot at least 3 times as long as terminal segment. Dorsal edge of furca with 5 combs of coarse teeth. Terminal claw of furca long and slender. California .....*H. reptans* Baird.
- aaa.* Length between 1 mm. and 2 mm. Furca with only terminal claws, lacking both terminal and dorsal setæ....*H. minnesotensis* (Herrick).

## 3. Sub-family Cypridinæ.

Natatory setæ reaching beyond end claws, or approximately to the tips of end claws. Second foot with a beak-like end segment and a claw.

- a.* Testes in form of concentric circles anteriorly. Shell tumid and excessively hairy. Furca normal, slender, no more than one-half length of shell. ....Genus *Spirocypris*.
- aa.* Testes, if present, not originating in anterior part of shell, and usually not in circles or half circles. Shell comparatively smooth..Genus *Cypris*.

## GENUS SPIROCYPRIS, SHARPE.

This genus was established to receive an excessively hairy Ostracod, having testes arranged on an unusually concentric whorl in anterior part of shell.

*a.* Shell about twice as long as high, excessively hairy. Testes arranged in form of about four concentric circles in anterior part of shell. Furca about one-half as long as shell. New Jersey.....*S. passica* Sharpe.

# GENUS CYPRIS, O. F. MÜLLER.

Natatory setæ reaching to tips of terminal claws or somewhat beyond.

Second antennæ five segmented in both male and female. Terminal segment of second foot beak-shaped, with a toothed hook-shaped claw. Furca normal, with two claws and two setæ.

The principal North American species are placed by Sharpe under two genera: Cypris and Cyprinotus.

All species of Cypris that are evidently sexual and have a row of tubercles on the right shell margin are placed under the sub genus Cyprinotus.

## KEY TO SPECIES OF SUBGENUS CYPRIS.

- a.* Length between 1 mm. and 2 mm.
  - b.* Both spines on first process of first maxilla smooth.
    - c.* Terminal claw of second foot as long as terminal segment. Caudal ramus weakly S-shaped.
      - d.* Subterminal claw of furca half as long as the terminal. Shell two-thirds as high as long. Mexico; Alabama...  
.....*C. virens* Jurine.
      - dd.* Subterminal claw of furca nearly as long as terminal. Shell one-half as high as long. Alabama.....  
.....*C. altissimus* Chambers.
  - bb.* Both spines on first process of first maxilla toothed.
    - c.* Shell not reticulated with broken lines.
      - d.* Shell less than twice as long as high. Terminal claw of furca half as long as furca.
        - e.* Subterminal claw of furca three fourths as long as terminal, both smooth. Illinois; Idaho; Mexico.  
.....*C. pellucida* Sharpe.
        - ee.* Subterminal claw two-thirds as long as the terminal. Illinois.....*C. fuscata* Jurine.
    - cc.* Shell reticulated. Terminal claw of furca about three-fifths as long as ramus. Terminal seta not more than one-fourth as long as terminal claw.....*C. reticulata* Zaddach.
- aa.* Length between 2 mm. and 3 mm.
  - Third and fourth segments of first foot fused. Shell spinous. Oregon. ....*C. pubera* O. F. Müller.

- aaa. Length 3 mm. or more.
- b. Both spines of maxillary process smooth. Dorsal margin of shell strongly convex, marked with dark bands.....  
.....*C. herricki* Turner.
- bb. Both spines of maxillary process toothed. Dorsal margin of shell nearly straight, marked with dark bands. Alabama.....  
.....*C. perelegans* Herrick.

## KEY TO SPECIES OF SUB-GENUS CYPRINOTUS.

- a. Dorsal seta of furca more than one-half length of subterminal claw.
- b. Dorsal seta at least twice width of furca from subterminal claw. Terminal claw of second foot strongly curved.....  
.....*C. incongruens* Ramdohr.
- aa. Dorsal seta of furca not more than one-half length of subterminal claw.
- b. Dorsal seta width of furca from subterminal claw.
- c. Shell yellowish-brown, marked with bluish-black longitudinal stripes on dorsum and sides, hairy.....  
.....*C. burlingtonensis* Turner.
- cc. Shell dirty brown, leathery in consistency, no markings.  
.....*C. testudinaria* Sharpe.
- bb. Dorsal seta twice width of furca from subterminal claw. Color yellowish green, shell marked with contorted lines, most noticeably on cephalic portion of valves.....*C. crena* Turner.

## 4. Sub-family Cypridopsinae.

Natatory setæ usually long. Second foot usually beak-shaped at tip, with a claw. Furca rudimentary, with a lash-like end bristle.

a. Shell broad from above, tumid. Branchial plate of from 2 to 5 plumose setæ. Parthenogenetic.....Genus *Cypridopsis*.

aa. Shell rather narrow from above. Second antennæ usually 4-segmented. Branchial plate of not more than 2 setæ. Sexual or asexual.....Genus *Potamocypris*.

## GENUS CYPRIDOPSIS, BRADY.

Shell very plump. Natatory setæ extending much beyond the terminal claws. Second foot five-segmented, with a strong claw at its extremity. Males unknown.

a. Three transverse dark bands on dorsal and lateral aspects of shell; very plump; common.....*C. vidua* O. F. Müller.



## GENUS POTAMOCYPRIS, BRADY.

Natatory setæ about as long, or somewhat longer, than end claws. Second antennæ usually four-segmented, armature of male coarser than that of female. Shell narrow from above, rather smooth.

Propagation sexual or asexual.

*a.* Furca cylindrical, turgid at base, suddenly narrowing to a bristle, which is little longer than the basal part. .*P. newtoni* Brady and Robertson.

*aa.* Furca broad, gradually narrowing to a bristle. Shell much compressed, grass green, at least dorsally. Mexico; Illinois.....*P. smaragdina* Vavra.

## 5. Sub-family Cyclopridinæ.

Natatory seta very long, usually twice as long as distance from their origin to tips of end claws. Second feet with 3 setæ. Furca usually normal.

*a.* Terminal segment of second foot small. Ductus of circlets of spine-like setæ, and a distinct central axis. Fourth segment of second antenna of male with 2 sense organs.....Genus Cypria.

*b.* Valves of shell of about same size. Right valve margin not usually crenulate.....Subgenus Cypria.

*bb.* Valves of shell of decidedly different sizes. Terminal margins of right shell crenulate.....Subgenus Physocypria.

*aa.* Terminal segment of second foot long and narrow, three times as long as broad. Ductus of numerous long filaments; no distinct central axis. Fourth segment of second antenna of male with no sense organ on distal end.....Genus Cyclocypris.

## GENUS CYPRIA, ZENKER.

Shell rather compressed. Second antennæ of male six-segmented, of female five-segmented, two sense organs on end of fourth segment. Natatory seta excessively long, reaching far beyond tips of terminal claws. Branchial plate of six setæ. Furca normal, stout.

The subgenus Physocypria is distinguished by: one shell higher or larger than the other, and the anterior and posterior margins of right shell crenulate. The subgenus Cypria includes the remaining Cypria forms. Seven species have been reported from America.

## SUBGENUS CYPRIA.

- a. Terminal short setæ of the second foot approximately equal.
- b. Terminal short setæ of second foot about as long as terminal segment.
  - c. Terminal claw of furca half as long as furca.
    - d. Shell covered with a close reticulum of longitudinally subparallel lines. Abdomen without processes. Michigan.....*C. exsculpta* Fischer.
    - dd. Shell plain, but with small puncta. Abdomen with 2 cylindrical processes.....*C. ophthalmica* Jurine.
  - cc. Terminal claw of furca three-fifths its length or longer.
    - d. Subterminal claw with well developed comb of teeth near top.....*C. dentifera* Sharpe.
- aa. Terminal short setæ of second foot evidently unequal.
  - b. Shell clear to brownish yellow, with a few scattered puncta. Dorsal seta of furca three times width of furca from subterminal claw.....*C. obesa* Sharpe.
  - bb. Shell white, shining, smooth, with numerous almost confluent puncta. Length 0.70 mm. Alabama.....*C. mons* Chambers.

## SUB-GENUS PHYSOCYPRIA.

- a. Left shell higher than right. Terminal short setæ of second foot about twice as long as terminal segment.....*P. pustulosa* Sharpe.
- aa. Left shell longer than right. Terminal short setæ of second foot only about as long as terminal segment.....*P. unequivalva* Turner.

## GENUS CYCLOCYPRIS, BRADY AND NORMAN.

Shells approximately same height. Second antennæ six-segmented in male, five-segmented in female, no sense organ on distal end of fourth segment.

Natatory setæ very long. Terminal segment of second foot three times as long as broad. Ductus of numerous long filaments, not on a distinct central axis, but all inclosed in a sack. Three species have been reported from America.

- a. Anterior edge of furca about twice as long as its terminal claw. ....*C. laevis* O. F. Müller.
- aa. Anterior edge of furca about two and one half times as long as its terminal claw.
  - b. The terminal claws of furca strong and much bent.....*C. forbesi* Sharpe.
  - bb. Terminal claws of furca slender and not bent.....*C. modesta* Herrick.

6. *Sub-family Candoninæ.*

Natatory setæ entirely lacking, or little developed. Second antennæ of female five-segmented, of male mostly six-segmented, and with two sense clubs. Terminal segment of second foot with 3 unlike setæ, 2 of which are directed backwardly.

- a. Shell not reticulated or honey-combed.
  - b. Furca normal. Branchial plate of 2 setæ. Eye present, small...  
.....Genus *Candona*.
  - bb. Furca abnormal. Anterior or terminal seta of furca missing. Eye rudimentary, disappearing with age.....  
..... Genus *Typhlocypris*.

## GENUS CANDONA, BAIRD.

Shell white, translucent. Natatory setæ of first antennæ shorter than entire antennæ. No natatory setæ on second antennæ. Furca strong. Can not swim, but creep along the bottom or burrow. Eight forms are reported for America.

- a. One of shorter setæ at tip of second foot sharply reflexed.....  
.....*C. reflexa* Sharpe.
- aa. Setæ at tip of second foot not reflexed.
  - b. Length of shell about 1.50 mm. Shell inequivalve, second foot six-segmented.....*C. crogmani* Turner.
  - bb. Length of shell about 1.25 mm. or less.
  - c. Furca curved.
    - d. Second foot six-segmented.
      - e. Claws of furca stout, terminal one one-third length of ramus.....*C. fabæformis* Fischer.
      - ee. Claws of furca slender, maxillary spines not toothed.
      - f. Color uniform, white to brownish.....  
.....*C. acuminata* Fischer.
      - ff. Color greenish, blotched with brown.....  
.....*C. delawarensis* Turner.
    - dd. Second foot five-segmented. Length 0.73 mm.....  
.....*C. simpsoni* Sharpe.
  - cc. Furca not curved.
    - d. Both claws of furca S-shaped....*C. sigmoides* Sharpe.
    - dd. Both claws of furca not S-shaped, both gently curved. Terminal claw half as long as furca.....  
.....*C. recticauda* Sharpe.

GENUS *TYPHLOCYPRIS*, VEJDOVSKY.

Forms in this genus resemble *Candona*, but lacking terminal seta of furca.

*a.* Terminal claws of furca of male about same size; in female one claw is about two-thirds length of other. Color greenish yellow with blotches of brown.....*T. peircei* Turner.

## II. Family Cytheridæ.

GENUS *LIMNICYHERE*, BRADY.

Shell strong, irregularly tuberculate or spinous, rather thin. First pair of antennæ five-segmented, second pair, four-segmented. Branchial plate of the mandible strongly developed (in other members of this group commonly rudimentary). Three nearly similar pairs of feet, all used for locomotion. Antennæ very little adapted for swimming. Furca rudimentary, commonly but two short bristles. Males uncommon.

*a.* Terminal segment of first antennæ seven times as long as wide. Furca cylindrical, about three times as long as wide. Terminal claws of second antennæ smooth.....*L. reticulata* Sharpe.

*aa.* Terminal segment of first antennæ four or five times as long as wide. Furca lamellar, six to seven times as long as broad, ending in a bristle. Terminal claw of second antenna of male armed with three or four strong teeth.....*L. illinoisensis* Sharpe.

## III. Family Darwinulidæ.

GENUS *DARWINULA*, BRADY AND ROBERTSON.

Shell smooth and fragile. Right shell larger than left. First antennæ shorter than in the Cyprididæ, and armed with stout setæ. Second antennæ four-segmented, with four or five terminal claws. First maxilla with a large branchial plate. First pair of feet five-segmented, and shorter than the second pair. Furca subconical, small.

*a.* First antennæ six-segmented, the second four-segmented. Antepenultimate segment of second antenna without a conspicuous one-jointed appendage.....*D. stevensoni* Brady and Robertson.

*aa.* First and second antennæ five-segmented. Antepenultimate segment of second antenna with a conspicuous one-jointed appendage, which terminates in one long and one short filament.....*D. improvisa* Turner.

## Order 3 Copepoda.

The Copepoda are small Crustacea, composed typically of about sixteen segments. They are never enclosed in a bivalve shell. They are ordinarily more or less elongated and cylindrical in form. The body is divided into two divisions, the cephalothorax and the abdomen. The anterior part, or cephalothorax, is composed of ten somites which are considerably united or fused. Five of these segments constitute the head and bear respectively the following appendages: first, a pair of several to many jointed antennæ, which serve in the free swimming forms for locomotion, and in the male

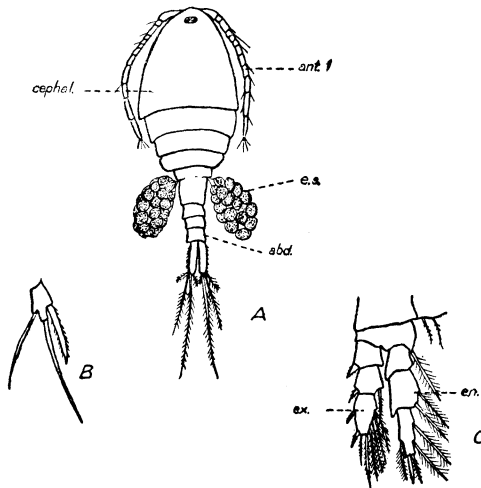


Fig. 9. A Copepoda. *Cyclops serrulatus* Fischer. A—Female. Length 1 mm. E.s., egg sac. B—Fifth foot. C—Fourth foot. Ex., exopodite; en., endopodite.

as prehensile arms for catching and holding the female during copulation; second, a pair of comparatively short, usually two-branched antennæ; third, a pair of mandibles, usually provided with a palpus; fourth, a pair of maxillæ of various form and function; fifth, a pair of maxillipeds which not infrequently subdivide in later life to form what appear to be two distinct pairs.

The five thoracic segments have each a pair of swimming feet consisting typically of a two-jointed base and two similar, gen-

erally three-jointed rami (Fig. 9C). The symmetry is frequently broken by the retardation of the development of the inner or outer ramus, while the fifth pair of feet may become rudimentary and in various ways subserve the organs of sex (Fig. 9B). The five abdominal segments are nearly devoid of appendages and are continued posteriorly by two caudal stylets which bear strong setæ, constituting, in many forms, a tail-fin or spring.

The females carry the eggs in external ovisacs. Sexual differences in the form and structure of the different parts of the body are almost uniformly found. All Copepoda, even such as are, in later life, parasitic, begin their existence as free-swimming nauplii.

Many Copepoda are ectoparasitic, especially on fishes (fish lice). They present a very interesting series of modifications, illustrating the degeneration of structure which so often accompanies parasitism. The peculiarity in structure of the Argulidæ,\* a small group of ectoparasites on fresh water fish (carp, stickleback, etc.), necessitates their separation from the rest of the Copepoda (Eucopepoda) as a separate branch called Branchiura.

Because of this degeneration in structure the study of the parasitic Eucopepoda and the Branchiura (all of which are parasitic) is too difficult for a beginner. Consequently all parasitic forms have been omitted from the following keys.

Though the vast majority of genera and species are marine, it would seem that the fresh-water Copepoda make up in the number of individuals what they lack in variety. Most members of this order are very prolific. It has been estimated that one Copepod may produce in a single year four billion five hundred million off-spring. These animals form a large part of the food supply of many of our most important food fishes, as well as the food of many other aquatic animals.

The Copepoda exhibit a great variety of structure, and their classification is attended with great difficulties. Some of the earlier classifications were based upon the character of the mouth and its appendages. This divided the free-living and semi-parasitic forms

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\*For a consideration of the parasitic Copepoda see Wilson, C. B. *Proc. U. S. Nat. Mus.*, XXV, XXVII-XXXIII, XXXV, 1903-1909.

from the true parasites. This division, although convenient, breaks down in many places.

More recently a classification of the free-living Copepoda has been founded upon the segmentation of the body and certain secondary sexual characters.

A study of the Copepoda is difficult because of the great number of species belonging to the genus *Cyclops* and, especially, to the genus *Diaptomus*.

	FAMILIES.	GENERA.
Copepoda	Centropagidæ	{ Epischura Osphranticum Limnocalanus Diaptomus
	Cyclopidaæ	{ Cyclops
	Harpacticidæ	{ Canthocamptus Marshia

#### KEY TO THE PRINCIPAL FAMILIES OF THE ORDER COPEPODA.

##### A. BRANCH EUCOPEPODA.

###### a. Sub-order Gymnoplea.

The division between the cephalothorax and abdomen falls immediately in front of the genital openings and behind the fifth thoracic feet. The latter in the male are modified into an asymmetrical copulatory organ.

- b. The cephalothorax is distinctly separated from the abdomen; the first antennæ are long and composed of 24-25 segments, in the male that of the right side modified and used as a clasping organ. The fifth pair of limbs are not rudimentary; a heart is present, and only one egg sac is found in the female. The second antennæ are distinctly biramous. See Fig. 10.....family Centropagidæ.

###### aa. Sub-order Podoplea.

The boundary between the fore and hind parts of the body falls in front of the fifth thoracic segment. The appendages of the fifth thoracic pair in the male are never modified as copulatory organs.

- b. The cephalothorax is clearly separated from the abdomen. Cephalothorax compact; ovoid; abdomen slender. First antennæ in the female shorter than the cephalothorax; in the male both of them are clasping organs. Second antennæ one branched. Fifth feet rudimentary; there is no heart. Egg sacs double, lateral. See Fig. 9....family Cyclopidaæ.

- bb.* The cephalothorax is not clearly separated from the abdomen. Body cylindrical or flattened. Antennæ short, not more than ten-jointed, both being clasping organs in the male. The second antennæ have a rudimentary outer ramus. The fifth pair of limbs are rudimentary and plate-shaped; a heart is absent. Egg sacs usually single. See Fig. 14.....  
.....family Harpacticidæ.

## B. BRANCH BRANCHIURA.

Carp lice. With large compound eyes, and long protrusible spine in front of the suctorial tube of the mouth; with four pairs of elongated biramous swimming feet. The members of this branch belong to the family Argulidæ.

### I. Family Centropagidæ.\*

The family Centropagidæ contains four recognized genera, *Epischura*, *Diaptomus*, *Osphranticum*, and *Limnocalanus*.

#### KEY TO THE GENERA OF THE FAMILY CENTROPAGIDÆ.

- a.* Furca with but three large terminal setæ to each ramus. Abdomen of male unsymmetrical, provided with lateral prehensile apparatus. Fifth pair of legs of female uniramous, 3-jointed, not terminating with a long spine, See Fig. 10.....*Epischura*.
- aa.* Furca with four large terminal setæ to each ramus.
  - b.* Inner ramus of first pair of legs 2-jointed; of the following three pairs 3-jointed. Fifth pair of legs in both male and female biramous, inner ramus rudimentary.....*Diaptomus*.
  - bb.* Both inner and outer rami of the first four pairs of legs 3-jointed. Fifth pair of legs in both sexes biramous, those of the female differing from the outer legs only by the presence of a strong inner hook on the second joint of the outer ramus; those of the male with the inner ramus 3-jointed and provided with plumose hairs, as in the other legs.
  - c.* Fifth pair of legs of female with the inner hairs of the last joint of the outer ramus transformed into short thick spines. In the male, outer ramus of the left leg of fifth pair with two joints; outer ramus of right leg with three.....  
.....*Osphranticum*.
  - cc.* Fifth pair of legs of female with the inner hairs of the last joint of the outer ramus long and plumose. Fifth pair of legs of male with both outer rami 2-jointed.....  
.....*Limnocalanus*.

\*Adapted and compiled from Schacht, Frederick William. Bull. Ill. State Lab. Nat. Hist., Art. 3, 1897; Art. 4, 1898, V. pp. 97-270, pl. XXI-XXXV.



## GENUS EPISCHURA, FORBES.

Cephalothorax more or less distinctly six-segmented. Abdomen (furca included) composed of five segments in the female and of six in the male; in the female, of the ordinary form, or flexed to the right and provided with a process on the right side of the second segment; in the male, straight or very slightly flexed, or strongly flexed to the right. Furcal rami hairy on the inner margin, provided in both sexes with three plumose terminal setæ, one slender simple seta at the inner apical angle, and a stout spine at the outer apical angle.

First pair of antennæ 25 segmented. Right male antennæ geniculate between the 18th and 19th segments; segments 19-21 and 22 and 23 ankylosed. Second pair of antennæ about as in *Diaptomus*.

All the swimming legs biramous, the outer ramus three-segmented, the inner, one-segmented. Fifth pair of legs of the female

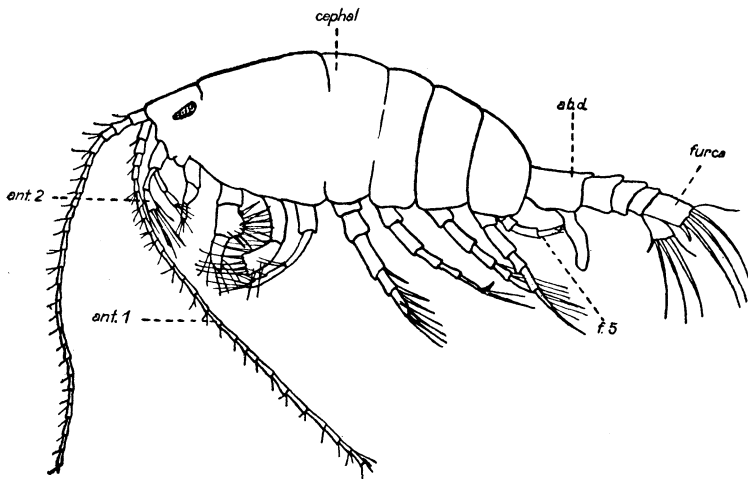


Fig. 10. *Epischura nevadensis* Lilljeborg. Female. Length 2.5 mm. Labels same as in Fig. 1.

alike, uniramous, three-segmented, the first segment of the ramus being, however, really the second basal segment, armed at the outer apical angle with a hair or delicate spine. Third segment armed with a varying number of spines (5-7).

Fifth pair of legs of the male unlike, uniramous, modified into a grasping organ. Right leg 2 or 3 segmented, last segment almost always flexed. Left leg three-segmented, the first segment produced on the inner margin to form a strong hook-like process; last segment variously armed.

Female generally bears spermatophore, and does not carry eggs in egg-sac.

Inhabits deep fresh water lakes.

#### KEY TO THE SPECIES OF EPISCHURA.

Based on the characters of the female.

1. Abdomen flexed to the right, second segment armed on the right side with a process. Furcal setæ and spines very broad. Fifth leg with last segment twice as long as the first, last segment armed with seven spines. Common North Central States.....*E. lacustris* Forbes.

2. Abdomen straight, second segment unarmed. Furcal spines and setæ of ordinary width.

3. Fifth legs very robust, first segment almost as wide as long, second segment sometimes armed with two spines, third segment armed with six (occasionally seven) spines. Quite common in Western United States.....*E. nevadensis* Lilljeborg.

4. Fifth legs slender, first segment considerably longer than wide, second segment armed with a single small spine; third segment armed with five (sometimes six) spines.....*E. nordenskioldi* Lilljeborg.

Based on the characters of the Male.

1. Abdomen straight, abdominal processes small and inconspicuous. Right leg three-segmented, the first segment armed on the inner margin with a hook. Second and third segments armed at the outer apical angle with a small spine. Process on first segment of left side but slightly curved.....*E. nordenskioldi* Lilljeborg.

2. Abdomen flexed to the right; abdominal processes large. Right leg two-segmented.

3. First segment of right leg with subtriangular toothed plate on the inner margin, and a hair at the outer apical angle. First segment of left leg very stout and strongly curved; second segment unarmed.....*E. nevadensis* Lilljeborg.

4. First segment of right leg entirely unarmed. First segment of left leg with comparatively slender process; second segment armed at the apical angle with a small spine.....*E. lacustris* Forbes.

#### GENUS OSPHRANTICUM, FORBES.

Cephalothorax compact, six segmented, the first two segments confluent above, the last segment produced into a bluntly-rounded

lobe on each side. Abdomen (furca included) composed of five segments in the female, of six in the male. Furcal rami hairy on the inner margins armed with five plumose setæ, the second from within the longest, and with a delicate smooth setæ on the inner margin of the dorsal surface. First pair of antennæ 23-segmented; right male antennæ geniculate between the 18th and 19th segments, and the 19th and 20th segments ankylosed. Second pair of antennæ, mandibles, and first, second, and third pairs of maxillæ as in *Diaptomus*, but stouter.

All the swimming legs biramous with three-segmented inner and outer rami; armed with stout setæ. In the female the legs of the fifth pair are alike, biramous, the rami three-segmented, the inner ramus the shorter. Fifth pair of legs of male biramous, dissimilar. Both rami of left leg three-segmented, the inner ramus the shorter. Outer ramus of right leg two-segmented, the inner three-segmented and like the inner ramus of the left leg. Egg-sac obovate.

Only one species, *Osphranticum labronectum*, Forbes, is known in North America. It is widely distributed, having been found in Alabama, Illinois, Minnesota, Oregon, and Wyoming.

#### GENUS LIMNOCALANUS, G. O. SARS.

Body long and narrow, the front armed with two hook-like processes. Cephalothorax widest at the middle, composed of six well-defined segments; last thoracic segment not produced laterally but slightly projecting posteriorly and armed on each side with a minute blunt spine. Abdomen slender, composed of four or five segments. Furcal rami very long, hairy on the inner margin; armed with five stout plumose setæ, and one slender setæ shorter than the rest, on the dorsal surface, near the inner margin and opposite the outer most of the other setæ.

First pair of antennæ shorter than the body, 25-segmented. Right male antenna geniculate between the 18th and 19th segments, each of which is armed with a hyaline lamina. Outer ramus of second pair of antennæ seven-segmented and armed with very long setæ.

All swimming legs biramous. Both rami of the four anterior pairs of legs three-segmented, the inner shorter than the outer.

Outer ramus of fifth pair of legs of female three-segmented. Inner ramus as in the other legs.

Outer ramus of right fifth legs of male two or, indistinctly, three-segmented. Outer ramus of left fifth leg two-segmented. Inner rami three-segmented. Eye single, near the lower margin of the head.

*L. macrurus*, Sars, is the only American representative of this genus. Reported from deeper northern lakes of North America.

#### GENUS DIAPTOMUS, WESTWOOD.

The genus *Diaptomus* is of special interest because it forms a large part of the food available for fishes. The genus occurs the world over, and is found not only in lakes but in running streams and in temporary pools.

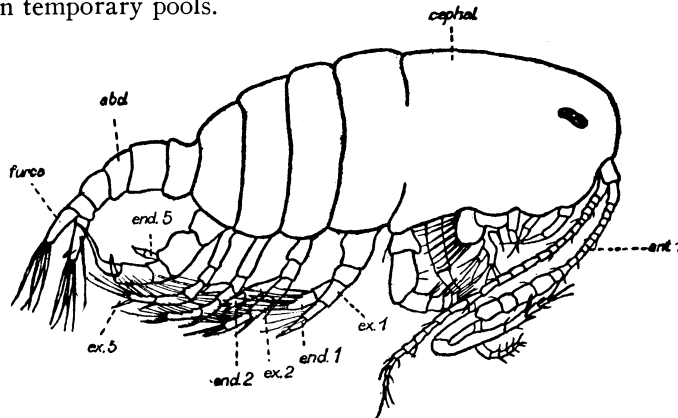


Fig. 11. *Diaptomus Eiseni* Lilljeborg. Male. Length 3.5 mm. Ant. 1, right first antenna geniculate; Ex. 1, 2, 5, exopodites, first, second, fifth legs; end. 1, 2, 5, endopodites, first, second, fifth legs.

It is very difficult, even for one who is acquainted with the genus, to recognize species without figures.

In some cases it is impossible to separate the females of related species.

The characters used for the determination of species are as follows:

1. The length of the antennæ, and the armature of the last three segments of the male antenna. This armature consists of

hyaline lateral lamellæ and a process on the antepenultimate segment, which varies, being sometimes a hook, more or less elongated, sometimes an elongated affair.

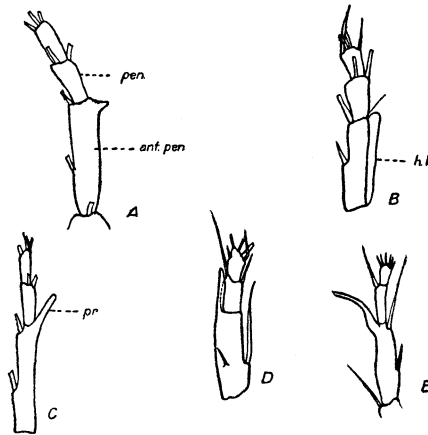


Fig. 12. Terminal segments of first right antenna of male. Pen., penultimate segment; ant. pen., antepenultimate segment; pr., process; h. l., hyaline lamella. A. *Diaptomus Birgei*, without distinct process on antepenultimate segment. B. *Diaptomus leptodus*, with hyaline lamella. C. *Diaptomus sicilis*, process nearly equals penultimate segment. D. *Diaptomus shoshone*, process exceeds length of penultimate. E. *Diaptomus Eiseni*, process curved.

2. The form of the fifth foot of the male. This has two basal segments. In the right foot the exopodite consists of 2 segments. The second segment bears a lateral spine and a terminal hook. The endopodite is 1 or 2 segmented. In the left foot the exopodite is composed of 2 segments, the second segment terminated with 2 processes. The endopodite is one or two segmented.

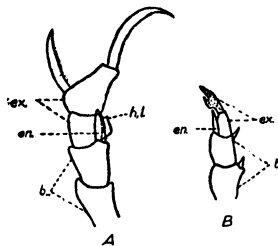


Fig. 13. Fifth feet, male of *Diaptomus Birgei*. A. Right foot. B. Left foot. B., basal segments; en., endopodites; ex., exopodites; h. l. hyaline lamella.

KEY TO THE NORTH AMERICAN SPECIES OF *DIAPTOMUS* BASED ON THE CHARACTERS OF THE MALE.\*

- I. Antepenultimate segment of the right male antenna without a distinct appendage.
  - a. Antepenultimate segment slightly produced at the distal end into a blunt point, first segment of right exopodite with marked quadrangular hyaline appendage. Indiana; Long Island; Wisconsin....  
.....*D. Birgei* Marsh.
  - aa. Right and left feet nearly equal in length, terminal hook of right foot symmetrical. One of most widely distributed of the North American species, north of the latitude of Northern Illinois.....  
.....*D. oregonensis* Lilljeborg.
  - aaa. Left foot shorter than right.
    - b. Left foot reaching beyond first segment of the exopodite.
      - c. Terminal hook of right foot uniaxial, right endopodite equal in length to first segment of the exopodite. Wisconsin; Michigan.....*D. Reighardi* Marsh.
      - cc. Terminal hook biangular, right endopodite large, longer than first segment of the exopodite. Mississippi; Louisiana; Florida .....*D. Mississippiensis* Marsh.
    - bb. Left foot reaching end of the first segment of the exopodite.
      - c. Inner process of the terminal segment of the left exopodite falciform, no hyaline appendage of first segment of right exopodite. Pretty well confined to Mississippi Valley, abundant in the middle and southern part of that region....  
.....*D. pallidus* Herrick.
      - cc. Inner process of terminal segment of left exopodite digitiform, a hyaline appendage on internal distal angle of first segment of right exopodite. Mountain region of West....  
.....*D. Tyrelli* Poppe.
- II. Antepenultimate segment of male right antenna with hyaline lamella.
  - a. Hyaline lamella broad, extending beyond the end of the segment, second basal segment of the right exopodite armed on the posterior surface with a small hook. Mississippi Valley..*D. leptopus* Forbes.
  - aa. Hyaline lamella narrow, extending beyond the end of the segment slightly, if at all, first basal segment armed with a hook equal in length to the first segment of the exopodite. Iowa; Nebraska; Colorado .....*D. clavipes* Schacht.
- III. Antepenultimate segment of the right antennæ bears a slender straight process.
  - a. This process is much shorter than the penultimate segment.
    - b. Right endopodite rudimentary.

\*Adapted from Marsh, C. Dwight. A Revision of the North American Species of *Diaptomus*. Trans. Wis. Acad. Sci., XV, pp. 381-516, pl. XV-XXVIII, 1907.

- c. Lateral spine of the second segment of the right exopodite is terminal. Yellowstone Park.....D. *Lintoni* Forbes.
    - cc. Lateral spine of the second segment of the exopodite is near the terminal proximal end, the antennal process is dentate on the outer margin. Oregon...D. *Trybomi* Lilljeborg.
  - bb. Right endopodite about equals in length the first segment of the exopodite, lateral spine median. Colorado.....D. *Judayi* Marsh.
- IV. The process of the antepenultimate segment of the right antennæ nearly equals, or equals, the penultimate segment.
  - a. The right endopodite equals in length the first segment of the exopodite, spines of the first basal segment large. Glen Lake, Saskatchewan .....D. *tenuicaudatus* Marsh.
  - aa. The right endopodite exceeds the length of the first segment of the exopodite, spines of the first basal segment small. Largely confined to large deep lakes, especially the Great Lakes; Nebraska; Yellowstone National Park.....D. *sicilis* Forbes.
- V. The process of the antepenultimate segment of the antenna exceeds in length the penultimate segment.
  - a. Large. Lateral spine of the second segment of the male exopodite is terminal or nearly so.
    - b. The antennal appendage only slightly longer than the penultimate segment, antennæ equal in length to cephalothorax. Lake Shoshone; Pike's Peak region.....D. *shoshone* Forbes.
  - bb. Antennal appendage exceeding in length the ultimate segment, antennæ reaching the furca. Washington....D. *Wardii* Pearse.
  - aa. Small. The lateral spine of the second segment of the right exopodite is on the proximal half of the segment, the antennæ reach beyond the furca.
    - b. Lateral spine of the second segment of the right exopodite short, right endopodite rudimentary. Common in Great Lakes and Lake St. Clair; Wisconsin; Michigan....D. *minutus* Lilljeborg.
    - bb. Lateral spine long, right endopodite equals in length the first segment of the exopodite. Michigan; Indiana; Oregon; Idaho; Washington; Yellowstone Park.....D. *Ashlandi* Marsh.
- VI. The antepenultimate segment of the right antenna bears a curved process.
  - a. The appendage equals or exceeds in length the penultimate segment.
    - b. The appendage about equals in length the last two segments; the second basal segment of the right foot is dilated on the inner margin, the endopodites are two-segmented. California; Nebraska.....D. *Eiseni* Lilljeborg.
  - bb. The appendage slightly exceeds in length the penultimate segment; second basal segment of the right foot not dilated on the inner margin, the left endopodite one-segmented. San Francisco, California.....D. *franciscanus* Lilljeborg.

- aa. The appendage is shorter than the penultimate segment.
- b. One or both terminal processes of the last segment of the left exopodite are distinctly falciform.
- c. The right endopodite is small, shorter than the first segment of the exopodite.
- d. Terminal segment of the right exopodite is elongate.
  - e. Right endopodite rudimentary, left endopodite two-segmented, spatulate in form.. Nantucket.....  
.....D. *spatulocrenatus* Pearse.
  - ee. Terminal segment of right exopodite much the broadest at the distal end, lateral spine nearly terminal and straight, left endopodite elongate.  
Louisiana.....D. *conipedatus* Marsh.
  - dd. Terminal hook of right exopodite falciform, lateral spine at the distal third of the segment, second basal segment of the right foot broad at the distal end with a process at the external distal angle. Massachusetts; New York to Minnesota; south to Alabama; Nebraska; Washington.....D. *sanguineus* Forbes.
  - ddd. Terminal segment of right exopodite of usual length.
    - e. Lateral spine terminal. Inner surface of left endopodite rugose, a very large species. Illinois; Minnesota; Ohio; Kentucky; Alabama.....  
.....D. *stagnalis* Forbes.
    - ee. Segments of right foot short and broad, terminal hook long and strongly curved, lateral spine long and straight. Nebraska.....D. *saltillinus* Brewer.
- cc. The right endopodite is distinctly longer than the first segment of the exopodite.
- d. The first segment of the right exopodite has an oblique ridge on its dorsal surface.
  - e. The first segment of the right exopodite has a transverse ridge, the lateral spine of the terminal segment is about one-half as long as the segment. Cuba.....D. *asymmetricus* Marsh.
  - ee. The first segment of the right exopodite has two curved processes on its dorsal surface, the lateral spine of the terminal segment equals or exceeds in length the segment. Louisiana ..D. *dorsalis* Marsh.
  - dd. The first segment of the right exopodite does not have a transverse ridge on the dorsal surface.
    - e. The lateral spine of the terminal segment of the right exopodite is terminal, the endopodites are distinctly two-segmented. California.....  
.....D. *Bakeri* Marsh.



- ee. The lateral spine is situated on the distal third of the terminal segment of the right exopodite, the right endopodite is indistinctly two-segmented, the left, one-segmented. Washington.....  
.....D. *Washingtonensis* Marsh.
- ccc. The right endopodite equals or only slightly exceeds the first segment of the exopodite.
- d. The terminal segment of the right exopodite has a transverse ridge on its dorsal surface, the lateral spine exceeds in length the segment. New Mexico; Mexico; Colorado .....D. *albuquerqueensis* Herrick.
- dd. The terminal segment of the right exopodite does not have an oblique ridge on its dorsal surface, the lateral spine is short, about one-half the length of the segment. New Mexico.....D. *novamexicanus* Herrick.
- bb. The terminal processes of the left exopodite are digitiform, the right endopodite shorter than the first segment of the exopodite.
- c. The right endopodite triangular in form, first segment of the exopodite without hyaline appendage. Colorado.....  
.....D. *nudus* Marsh.
- d. The first segment of the right exopodite with hyaline appendage.
- e. Appendage at the inner distal angle, endopodite about equals the first segment of the exopodite. California; Nevada; Colorado.....  
.....D. *signicauda* Lilljeborg.
- ee. Appendage on inner distal half, quadrangular in form, endopodite much shorter than the first segment of the exopodite. California; Iowa; Illinois; Indiana; Wisconsin; Colorado; Nebraska.....  
.....D. *silicoides* Lilljeborg.
- dd. The first segment of the right exopodite with a transverse ridge, second segment with oblique ridge and hyaline process near the outer margin. Cuba.....  
.....D. *purpureus* Marsh.

## II. Family Cyclopidae.

The only free-living, fresh water representatives of this family belong to the genus *Cyclops*.

Pond water abounds everywhere with little pear shaped creatures belonging to the genus *Cyclops*. These, too, are often called "water fleas," because they swim about with a series of jerks much in the same manner as the *Daphnia*.

In spite of its minute size, it is easily recognizable by its elongated form, its rapid, jerky movements, and by the egg sacs of the female.

The body of *Cyclops* is flattened on the ventral and convex on the dorsal side. The head and thorax, cephalothorax, form the larger part of the body, and the carapace which covers this part terminates in front into a curved rostrum. (Fig. 9A).

The antennules are very large, and form the principal organs of locomotion. In the male they are modified by a peculiar form of joint and long setæ, as clasping organs, used for holding the female during copulation.

The antennæ are much shorter than the antennules and are uniramous.

The eyes are both fused into one dark mass of a globular form in the middle of the forehead, a feature which has suggested a resemblance to the one-eyed giants of Greek mythology. Hence the name *Cyclops*.

Mandibles and maxillæ are present, and the first four thoracic appendages bear biramous swimming feet. The fifth thoracic segment bears a pair of rudimentary legs. (Fig. 9B).

There are five free thoracic segments; the last bears the genital opening, and is fused in the female with the first abdominal.

There are four abdominal segments, the last bears a pair of caudal stylets (*furca*) produced into plumed setæ.

Attached to the enlarged portion of the body of the female, there is a pair of large pear-shaped egg sacs, in which the eggs are carried until the young are hatched.

The males are much smaller than the females.

#### GENUS *CYCLOPS*, O. F. MÜLLER.

##### KEY TO SPECIES OF *CYCLOPS* FOUND IN NORTH AMERICA\*

Note. This key is based on the characteristics of mature female. It includes only those members which are recognized members of the American fauna. See Fig. 9B for structure of fifth foot.

##### I. Antennæ composed of seventeen segments.

- a. Fifth foot composed of one segment, armed with one spine and two long setæ. A large species of dark color. Minnesota; Wisconsin; Michigan; Illinois.....*C. ater* Herrick.

\*From Marsh, C. Dwight. A Revision of the North American Species of *Cyclops*. Trans. Wis. Acad. Sci., XVI, part 2, pp. 1067-1135, pl. LXXII-LXXXI, 1910.

- aa. Fifth foot composed of two segments.
    - b. Second segment of fifth foot armed with seta and short spine.  
Common .....*C. viridis* Jurine.
    - bb. Second segment of fifth foot armed with two setæ.
      - c. The second segment of the fifth foot is elongate, its length as much as twice its width, the seta of the inner distal angle spine-like, less than one-half the length of the outer seta. Northern states, north of Ohio River...*C. bicuspidatus* Claus.
      - cc. The second segment of the fifth foot is shorter, length less than twice its width, armed with two nearly equal setæ.
      - d. The seventeenth antennal segment is armed with a serrate hyaline plate.....*C. Leuckarti* Claus.
      - dd. The seventeenth antennal segment is not armed with a hyaline plate. Arizona.....*C. tenuis* Marsh.
    - bbb. The second segment of the fifth foot is armed with three setæ.
      - c. The twelfth antennal segment has a sensory club, the egg sacs stand out from the abdomen, the hyaline plate of the seventeenth antennal segment is serrate, or smooth. Common .....*C. albidus* Jurine.
      - cc. The twelfth antennal segment has a sensory hair, the egg sacs lie close to the abdomen, the hyaline plate of the seventeenth antennal segment is deeply notched. Widely distributed, but nowhere very abundantly.....*C. fuscus* Jurine.
- II. Antennæ composed of sixteen segments, fifth foot of three segments. Alabama; Wisconsin; Wyoming; Pennsylvania....*C. modestus* Herrick.
- III. Antennæ composed of twelve segments, fifth foot of one segment.
  - a. Fifth foot armed with three setæ, rami of swimming feet of three segments.
    - b. Furca of variable length, armed externally with a row of spines. Found almost everywhere.....*C. serrulatus* Fischer.
    - bb. Furca short, without spinous armature, a small limnetic species. Widely distributed, especially in lakes.....*C. prasinus* Fischer.
  - aa. Fifth foot armed with one seta, rami of swimming feet of two segments.....*C. varicans* Sars.
- IV. Antennæ composed of eleven segments.
  - a. Rami of swimming feet composed of three segments. Widely distributed, but not abundant anywhere.....*C. phaleratus* Koch.
  - aa. Rami of swimming feet composed of two segments. Widely distributed, although nowhere common.....*C. bicolor* Sars.
- V. Antennæ composed of eight segments. Not common.....*C. fimbriatus* Fischer.
- VI. Antennæ composed of six segments.....*C. aequoreus* Fischer.

## III. Family Harpacticidæ.\*

Numerically the largest of the families of the Copepoda, this group contains mostly marine forms. Of the over thirty genera of this family less than a half dozen are not exclusively marine, and most of these live in brackish waters.

The general form and structure closely resemble that of the Cyclopidae. The following characters are the more important ones in distinguishing the family from the other families of the order:

Body flattened or sub-cylindrical. Abdomen usually not much smaller than the thorax, from which it is not separated by a sudden constriction; antennæ rather short, 4 to 10 jointed; mandibles strongly toothed, palpate; maxillæ well developed, palpate; first maxillepeds with strong teeth at the end, second pair usually forming a claw. The first pair of feet are often turned forward or prehensile; fifth pair one or two jointed, serving as egg supports in the female.

Most species live among sub-aquatic vegetation.

*Sub-family Canthocamptinæ.*

Distinguished from the other sub-families of Harpacticidæ by the fact that the second maxilleped has a prehensile hook. The feet of the first pair are not clawed, but have the inner branch elongated, and the palp of the mandible is one branched.

## GENUS CANTHOCAMPTUS, WESTWOOD.

These little animals may be secured in considerable numbers by gathering a supply of water from among weeds in shallow ponds.

Canthocamptus is an elongated animal, with the body divided rather obscurely into two portions, of which the first, or anterior portion, is the larger. This part of the body has five segments, each of which has at least one pair of appendages.

As seen from above, it is triangular and extends in front into a short stout beak. Above the beak in the center of the forehead, is the eye. The appendages of the anterior part of the body are: an-

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\*Compiled and adapted from Herrick, C. L. and Turner, C. H. Synopsis of the Entomostraca of Minnesota, 1895.

\*Key from Pearse, S. A. Contributions to the Copepoda Fauna of Nebraska and Other States. Studies Zool. Lab. Univ. Neb., IV, pp. 145-160, pl. XIII-XVIII, 1905.

- cc. Anal plate without spines. Nebraska....*C. hiemalis* Pearse.  
 ccc. Spines on anal plate not bifid. Nebraska.....  
 .....*C. staphylinoides* Pearse.

GENUS MARSHIA, HERRICK AND TURNER.

Inner branch of first foot three-jointed, scarcely elongated, barely sub-prehensile. Second and third feet with outer ramus two-jointed, short. Fourth foot with minute one-jointed outer ramus and three-jointed inner ramus. Fifth feet one-jointed. Antennæ six-jointed, the fourth joint with a slender hyaline process longer than the end of the antennæ. Second antennæ without obvious palpus, prehensile. Antennæ of the male strongly modified.

Two species are reported belonging to this genus:

*M. albuquerqueensis* and *M. brevicaudata*.

1. Antennæ short, six-jointed. Antennules short, prehensile. Stylet two and a half times as long as wide. The two median apical setæ are fused at the base and the inner is three times as long as the outer, which is twice as long as the stylet. Inner apical seta is short.

In the male the antenna is greatly reduced. Caudal stylet over four times as long as wide.....*M. albuquerqueensis*.

2. Caudal stylets short, and twice as long as broad, the longest seta seven times length of stylet. Setæ not fused at base.....  
 .....*M. brevicaudata*.

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